MUSHROOM
RESEARCH
STATION
YAXLEY
PETERBOROUGH

# FINAL REPORT 1954

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# FINAL
# REPORT
# 1954

YAXLEY · PETERBOROUGH
ENGLAND

# Contents


| | Page |
|---|---|
| Preface by the Chairman .. .. .. .. | 3 |
| Board of Directors .. .. .. .. .. | 4 |
| Staff .. .. .. .. .. .. .. | 4 |
| General Report by the Director .. .. .. | 5 |
| Chemistry Department .. .. .. .. | 7 |
| Cropping Experiments .. .. .. .. | 18 |
| Microbiology Department .. .. .. .. | 24 |
| List of Publications .. .. .. .. .. | 33 |

# CHAIRMAN'S PREFACE

These words are being written at an anxious moment. There has been a definite reduction this year in the area put down to mushrooms, particularly in the South of England, because of the depredations of a species of Phorid fly believed by many to be resistant to the customary insecticides. There has been a return in the autumn of Yellow Mould which in severe concentrations is coincident with a serious fall in yield. For these and other reasons less easily identified, few farms have had a really good year, and it is singularly unfortunate that, during the last quarter of 1954, research was in abeyance.

On 30th September the Yaxley Station of the Mushroom Research Association closed its doors. Our chemist and his assistant moved to Rothamsted and our microbiologist went to Wye. Our Director of Research stayed on to wind up the last two experiments, to finish this Report, and to pack off the laboratory equipment to Littlehampton.

A resumption of work on mushrooms is unlikely before the Spring of 1955, and it may well be confined to the laboratories until the Summer. The experiment houses have yet to be built, and during the interim we must restrain our impatience and seek consolation in the knowledge that 1955 should see mushroom research on sounder foundations than it ever was or could have been at Yaxley. *After the disasters of* 1953, *who could seriously believe that growers would have subscribed enough money to see the MRA safely through this year*?

The Directors of the MRA are hoping that, before they finally depart from office, a mutually-satisfactory liaison will have been established between the Mushroom Growers' Association and the Board of Management of the Glasshouse Crops Research Institute.

This is our last Report, and in my final Preface I would like to thank all past members of the Yaxley Staff for their loyal endeavours and to wish all who will be engaged in future research the greatest possible enjoyment in their fascinating field. Would that I were technically qualified to be with them!

Thank You, too, to all who have at any time subscribed to the Station's funds and so enabled us to keep the flag flying since 1946. And especially may I express my personal gratitude to my fellow Directors on the MRA Board and to Dr. Ronald Edwards for the encouragement and support they have unfailingly given me during the four years I have had the honour of serving the Industry as Chairman. We have done our best, and I believe we have written an important chapter in the history of the Mushroom Industry in Europe.

FRED. C. ATKINS,

*Chairman*, 1950-51, 1953-54.
*Managing Director*, 1946-54.

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# GENERAL REPORT

*By the Director of Research*

In this Report on the work of the Station, a more personal note may be permissible than is usual in such publications.

I therefore wish to take this opportunity of paying my personal tribute to the vision and determination of the founders of the Association, who made possible its existence during the past nine years, and provided facilities for the work which has been done at Yaxley during that period. The same spirit is shown by their successors on the present Board, including some of the original members, who are giving all the equipment of the Research Station to the new Glasshouse Crops Research Institute for use in the same work which is to continue there, and who have announced their intention of applying any surplus funds of the Association for similar purposes.

There must be many growers and others in the mushroom industry who have no idea of the origin of MRA, and I make no apology for reminding them that whatever the MRA has done would not have been done without the five pioneers, Major C. P. Whitaker, S. Middlebrook, Fred. C. Atkins, J. G. Hughes, and C. L. Sinfield, and the twenty or so members who joined with them in maintaining the Research Station during the three years of its existence as a private Station.

At the same time I wish to thank the many growers and others concerned in the industry who have encouraged us by their help and interest, and last but not least the members of the Research Station staff who have all made their contribution to its work, and to the results which have been published in this series of Reports.

I hope those who are joining the new Institute will settle down quickly in their new premises and go on to solve the problems we have had to pass on, and others which will undoubtedly arise in the future.

During this, the last year of the work of the Station, four cropping experiments have been completed as usual, but laboratory work and experiments on diseases ended in September when the laboratory was closed.

The four cropping experiments were on the same general subject of artificial casing mixtures and their management. Results of these and previous similar experiments have not been as clear-cut as one would have liked, and the subject is obviously complicated.

More precise control of ventilation and air circulation in the house would reduce variations which were found, for example in the evaporation from beds which was much greater at one end of the house, until screens were placed so that a current of air could not blow straight along the shelf; cross currents being more likely to be equal over all the beds into which a shelf is divided.

There have been some experiments in which variations in casing mixture or treatment have produced no appreciable effect on the yield, but where there have been differences they have supported the following two main conclusions.

1. The most porous, absorbent casing materials tend to give best results.
2. A greater depth of casing, up to 2 inches, gives better results than the customary $1\frac{1}{2}$ inches.

This requirement, a very porous absorbent casing 2 inches thick, is most important where air conditions tend to be dry, and ventilation and air circulation vigorous. Under humid conditions or whenever evaporation from the beds is slow, less porous and thinner casings may do equally well.

There has also been evidence from earlier experiments with soils, and from some of these with artificial casing mixtures, to show that the crop suffers if the pF of the casing is too high, i.e., if its moisture is held too tightly.

The study of physical properties of peat and its mixtures has continued, and is fully reported later. Although it has proved its value as a commercial casing material and has contributed a great deal to our knowledge of artificial casing mixtures, peat has been found too variable for the more precise work which is now becoming desirable. Its compressibility is particularly inconvenient in this respect.

One of the practical problems in the use of peat is how wet it should be. It must hold enough water, loosely enough to give it up to the mushrooms, but should not, for convenience of handling, be so wet that water runs out whenever it is touched; this could injure spawn when casing. It seems that up to half a gallon of water per pound of sphagnum peat can be added without much risk of this happening, but the margin of safety is increased if the peat is allowed several hours in which to absorb the water before it is used for casing. Absorption continues up to 24 hours after adding water to peat, and during all that time the water is being more firmly bound. At the end of it there should still be enough loosely held water to satisfy the needs of the mushroom bed.

**Diseases**

The principal subject in this field has been the well-known yellow moulds found in mushroom beds, either in the compost or between compost and soil. It has been quite clearly shown that there are several of them, three being widely distributed, and none of these three is identical with available specimens or the original description of *Myceliophthora lutea*, which has long been regarded as the offender when this trouble occurs in commercial beds. It still remains to establish the identity of these three fungi, and to determine which of them, if any, are actually harmful, but at least the problem has been more clearly defined.

# CHEMISTRY DEPARTMENT
## P. B. Flegg

**The water holding properties of peat**

It was found (Annual Report, 1953) that the main obstacle to rapid and complete saturation of peat with water was the presence of trapped air, and that procedures facilitating the removal of this air would reduce the time to reach complete saturation. This problem has been further investigated. The criterion of complete saturation has been taken to be the point at which the peat sinks to the bottom of the water and none remains floating. In the following experiments a fixed weight of air-dry peat was immersed in 500 ml. water and occasionally stirred. The time taken for all the peat to sink was noted. All treatments were duplicated and where necessary the experiments were repeated to confirm the results. In all the experiments agreement between duplicates was good and results were reproducible.

Table 1 shows the effect of reducing the air pressure above the peat being soaked, compared with wetting under atmospheric pressure. This treatment has already been reported (Annual Report, 1953) to increase the rate of wetting. The German sphagnum peat has been found to take up to 13 days to become saturated when soaked in cold water. It can be seen that using water at 55° C. three-quarters of the peat had sunk within 20 hours. Under reduced pressure (15 cm. mercury) the rate of wetting was much increased, complete saturation in cold water being reached in less than 5 hours and in hot water in less than an hour. Sedge peat responded to these treatments in a similar manner, being generally easier to saturate than the sphagnum types.

Instead of removal of the trapped air as previously described, an increase in rate of wetting should be possible by reduction of the surface tension of the water. The effect of a higher temperature of the water has already been noted. Table 2 shows the increase in rate of wetting with increasing initial water temperature. Immersed in water at 95° C. the German sphagnum peat was saturated within 1 hour, at 75° C. within 5 hours and at 55° C. within 24 hours. In cold water (8·5° C.) only a small amount of peat had sunk after 2 days. The effect of several surface active agents has also been examined in water at 55° C. The results are given in Table 3. 0·5% Teepol and sodium lauryl sulphate both increased the rate of wetting of German sphagnum peat, but a third wetting agent had no effect. The effect of these agents on the rate of wetting of medium grade English sedge peat was negligible.

Other methods of wetting peat which were relatively unsuccessful including soaking in 10% methyl alcohol, steaming, and compression of the peat under cold water.

It was decided to adopt overnight soaking in water at 55° C. under reduced pressure (about 15 cm. mercury) as the standard method of

**Table 1. Wetting of peat: effect of reduced pressure**

| German sphagnum peat | After 1 hour | 2 hours | 20 hours |
|---|---|---|---|
| Atmospheric pressure— | | | |
| Cold water .. .. .. | — | — | + |
| Hot water 55° C. .. .. | + | ++ | +++ |
| Under reduced pressure— | | | |
| (15 cm. mercury) | | | |
| Cold water .. .. .. | + | +++ | ++++ |
| Hot water 55° C. .. .. | ++++ | ++++ | ++++ |
| **English sedge peat** | **After 1 hour** | **3 hours** | **24 hours** |
| Atmospheric pressure— | | | |
| Cold water .. .. .. | — | + | ++ |
| Hot water 55° C. .. .. | +++ | +++ | ++++ |
| Under reduced pressure— | | | |
| (15 cm. mercury) | | | |
| Cold water .. .. .. | +++ | ++++ | ++++ |
| Hot water 55° C. .. .. | ++++ | ++++ | ++++ |

**Table 2. Wetting of German sphagnum peat: effect of temperature**

| Initial water temperature °C. | After 1 hour | 5 hours | 24 hours | 48 hours |
|---|---|---|---|---|
| 8·5 | — | — | + | + |
| 35 | — | + | ++ | +++ |
| 55 | + | +++ | ++++ | ++++ |
| 75 | ++ | ++++ | ++++ | ++++ |
| 95 | ++++ | ++++ | ++++ | ++++ |

\+ one quarter of the peat had sunk
++ one half „ „ „ „ „
+++ three quarters „ „ „ „ „
++++ all „ „ „ „ „

saturating peat. It has been found (Annual Report, 1953) that boiling the peat for 10 minutes had no effect on water holding properties but soaking in hot water seemed a less drastic procedure. This method also avoided the addition of chemicals, and consequent unknown effects upon water holding and other properties.

A comparison of the rates of wetting of several types of peat was made in water initially at 55° C. The results are shown in Table 4. The German and Irish peats were very similar in appearance and there was very little difference in their rates of wetting. The three grades of English sedge peat (Annual Report, 1953) have already been compared by soaking in cold water. This sedge peat was more easily wetted than the sphagnum peats, which may be important in practice. The effect of larger aggregate size on the rate of wetting can be seen. It is to be expected that air would be more readily removed from smaller aggregates and that wetting would therefore be more rapid.

**Table 3. Wetting of peat: effect of surface active agents at 55° C.**

| | After 1 hour | 2 hours | 20 hours |
|---|---|---|---|
| German Sphagnum peat— | | | |
| Water | — | + | +++ |
| 0·5% Teepol | + | +++ | +++ |
| 0·5% Sodium lauryl sulphate | - | - - - | - - - |
| 0·5% EDTA (ethylenediamine tetra-acetic acid) | + | + | +++ |
| Somerset sedge peat— | | | |
| Water | + | +++ | +++ |
| 0·5% Teepol | ++ | - - - | - - - |
| 0·5% Sodium lauryl sulphate | - - | - - - | - - - |
| 0·5% EDTA | ++ | +++ | +++ |

**Table 4. Wetting of peat: effect of particle size and type of peat (at 55° C.)**

| Type of peat | After 1 hour | 2 hours | 19 hours |
|---|---|---|---|
| German sphagnum | + | ++ | +++ |
| Irish sphagnum fine | + | ++ | +++ |
| Irish sphagnum coarse | + | + | +++ |
| English sedge < $\frac{1}{8}$″ (A) | +++ | ++++ | ++ - - |
| English sedge $\frac{1}{8}$″—$\frac{3}{8}$″ (B) | ++ | +++ | ++ - - |
| English sedge $\frac{3}{8}$″—$\frac{5}{8}$″ (C) | - - | - - | - - - |

**Movement of water**

The moisture-suction curve method described in the Annual Report for 1953 has been used to study the movement of water from saturated to air-dry peat. Peat saturated by the method described previously was mixed with air-dry peat and kept in air tight jars for periods up to 7 days. Figure 1 shows the curves obtained from German sphagnum peat mixed in equal proportions based on dry weight of peat, examined after 15 minutes, 1 day and 4 days in contact. Curve I is the curve obtained from the peat which had been mixed 15 minutes. Very little transfer can have taken place and the characteristics of the curve must be due almost entirely to the saturated peat. Curve II obtained from a mixture which had been mixed for 24 hours shows that some of the more loosely held water from the saturated peat has been absorbed by the air-dry peat and the total volume of water held against a suction corresponding to pF 2·5 was 42% compared with 33% before any transfer has taken place. After 4 days in contact the curve obtained corresponds very closely with curve II. This indicates that movement of water from saturated to air-dry peat took place within 24 hours and thereafter there was little or no movement. A similar experiment in which saturated peat was mixed with air-dry peat in the ratio of 2 : 1 showed a very similar result. It seemed possible that the extra amount of water might cause movement to take place over a shorter period but there was little movement after only 4 hours and movement was complete after 24 hours.

Figure 2 shows a similar experiment using equal proportions of saturated and air-dry sedge peat, grade $\frac{1}{8}$″—$\frac{3}{8}$″. In this case movement of water was still taking place 24 hours after mixing. This may be partly due to the different character of the sedge peat which consisted of hard lumps compared with the fibrous nature of the sphagnum peat.

The loss of water from saturated peat during air drying was also investigated by the suction curve method. Peat saturated by the standard procedure was laid out in glass dishes about 1″ deep and left in the open for 15 minutes, 1 day and 3—5 days. The surface of the peat was disturbed occasionally to secure more even drying.

Figure 3 shows the curves obtained from a German sphagnum peat. Curve I was obtained almost immediately after exposure to air and there was practically no loss by evaporation. Curves II and III were obtained after 1 and 5 days respectively. The greatest loss was of water which was held less firmly, at low pF values, but there was some loss of water held at the highest tension measured. This may have been due to excessive drying at the surface of the peat.

Figure 4 shows the results of a similar experiment using sedge peat $\frac{1}{8}$″—$\frac{3}{8}$″. In this case only water held at tensions less than pF 1·3 was lost within 3 days drying. The more firmly held water was retained. This may be due to mixing the peat more often and preventing excessive drying of the surface layer. In both cases the more loosely held water was lost more readily under conditions of drying out at room temperature. This is to be expected.

**Figure 1—Movement of water from saturated to air-dry German sphagnum peat packed at 11g. per 100 ml.**

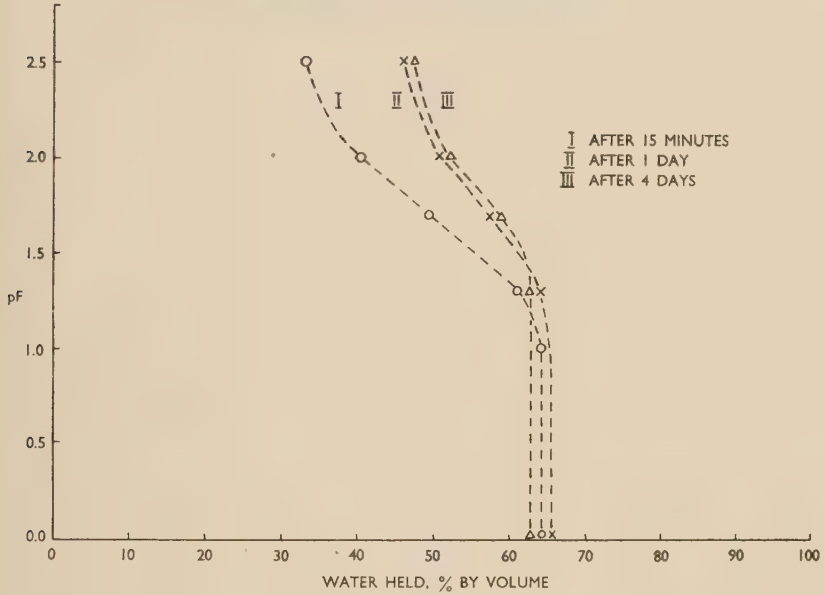



**Figure 2—Movement of water from saturated to air-dry English sedge peat packed at 20 g. per 100 ml.**

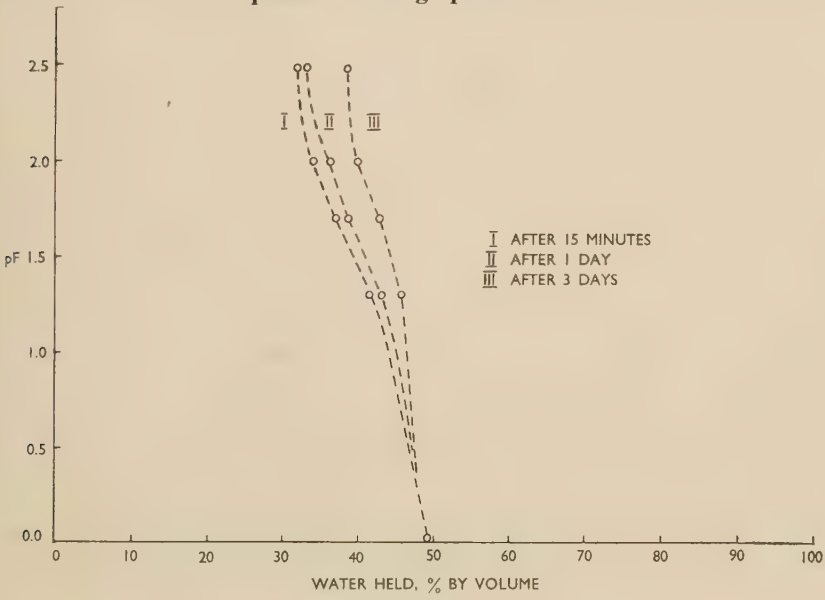


**Figure 3—Evaporation of water from saturated German sphagnum peat packed at 9 g. per 100 ml.**

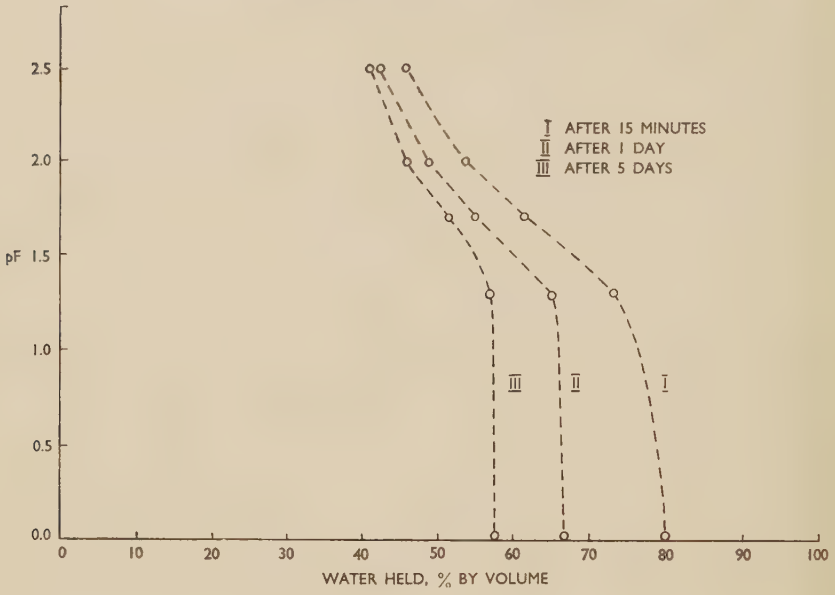
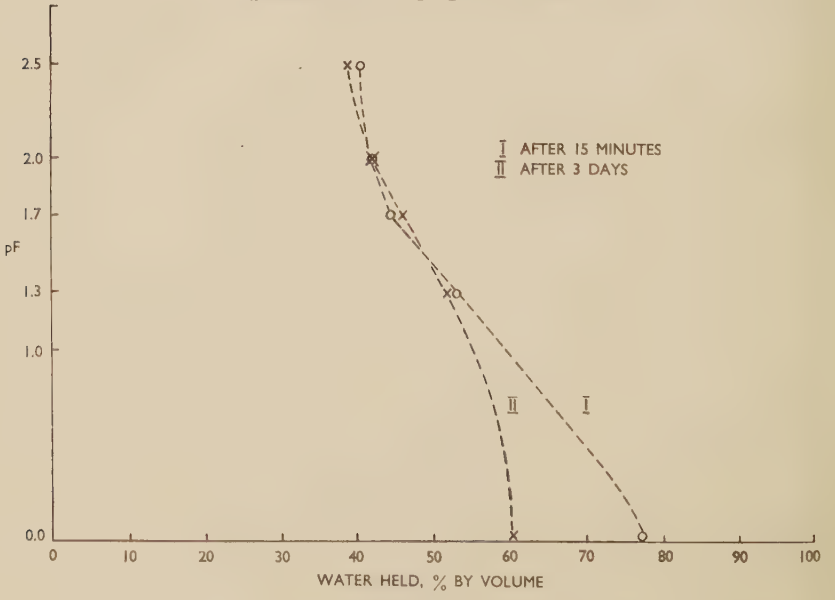



**Figure 4—Evaporation of water from saturated English sedge peat packed at 20 g. per 100 ml.**



**Effect of previous treatment and variability**

In order to determine the effect of excessive drying upon the subsequent water holding properties of peat, samples were oven dried at 90° C. for 20 hours and then saturated in the normal way. These were compared with air-dry samples from the same sources. Three samples were taken from each of three bales of a German sphagnum peat to give an estimate of variation within and between bales. After saturation the peat was packed at 8 g. per 100 ml. and was subjected to a suction corresponding to pF 2·5 for 30 minutes. The results are shown in Table 5. Oven drying significantly ($P < 1\%$) reduced the water holding properties of the peat. This is no doubt due to irreversible changes in the peat due to excessive drying. Heating at 90° C. for 20 hours is a fairly drastic treatment but it seems probable that excessive drying during the production of peat moss would have a detrimental effect upon the water holding properties.

In view of the difficulties involved in controlling the drying of peat dug for horticultural purposes some variation within the peat grades supplies is to be expected. From Table 5 it is evident that variation within a given bale was small. It was found to be slightly higher in other experiments, the greatest variation found in a bale was $53{\cdot}9 \pm 3{\cdot}4$. However variation between bales was fairly high, indeed it was possible also to detect differences in colour and texture between bales.

The possibility that liming the peat affects water holding capacity has been mentioned (Annual Report, 1953). Further work on this aspect led to very variable results. The reasons for this have not been found and further work is required.

**The compressibility of peat**

The effect of the weight of peat in a given volume on water holding properties has already been demonstrated (Annual Report, 1953). Peat is so easily compressed that the weight of peat in a given volume

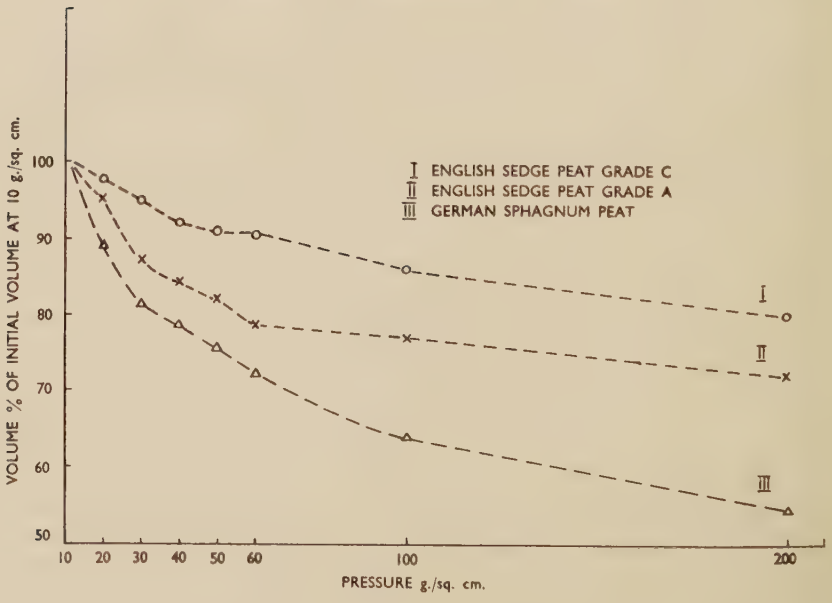
**Table 5. Water holding capacity of German sphagnum peat: effect of pre-treatment**

| | Water held by volume % at pF 2·5 (means of 3 determinations) | |
|---|---|---|
| | air dried before soaking | oven dried before soaking |
| Bale 1 .. .. | $37{\cdot}0 \pm 0{\cdot}2$ | $29{\cdot}5 \pm 1{\cdot}1$ |
| Bale 2 .. .. | $34{\cdot}5 \pm 0{\cdot}3$ | $29{\cdot}0 \pm 0{\cdot}2$ |
| Bale 3 .. .. | $44{\cdot}2 \pm 1{\cdot}4$ | $33{\cdot}0 \pm 1{\cdot}1$ |

can vary considerably according to the amount of compression. In order to investigate this, a simple piece of apparatus was devised consisting of a cylinder in which fitted a plunger. Peat was placed in the cylinder, the plunger was placed in position and weights were added. The pressure applied through the plunger was measured in g./sq. cm. With increasing pressures the decrease in volume of the peat was noted. The results obtained from sphagnum and sedge peats are shown in Figure 5. The sedge peat samples which were much harder in texture were less compressible than the fibrous sphagnum peat.

Similar measurements were made with sphagnum peat and sand mixtures. Three sets of measurements were made and the decrease in volume of each mixture under a pressure of 200 g./sq. cm. (about 3 lb./sq. in.) is shown in Figure 6. There is some variation between the three sets of figures but this is not surprising. Peat and sand mixtures are very difficult to handle without separation occurring. The mixtures containing more than 50% by volume of sand are, as would be expected, less easily compressed. Sand alone was not altered by the pressures used and the expected percentage decrease in volume of the mixtures is shown on the graph as a straight line. However the mixtures containing approximately equal volumes of sand and peat were not compressed as much as expected. This further complicates comparison of the water holding properties of peats and peat mixtures as it is important that the packing of different mixtures should be the same. Changes in the packing of a mixture will result in changes in the moisture-suction curves.

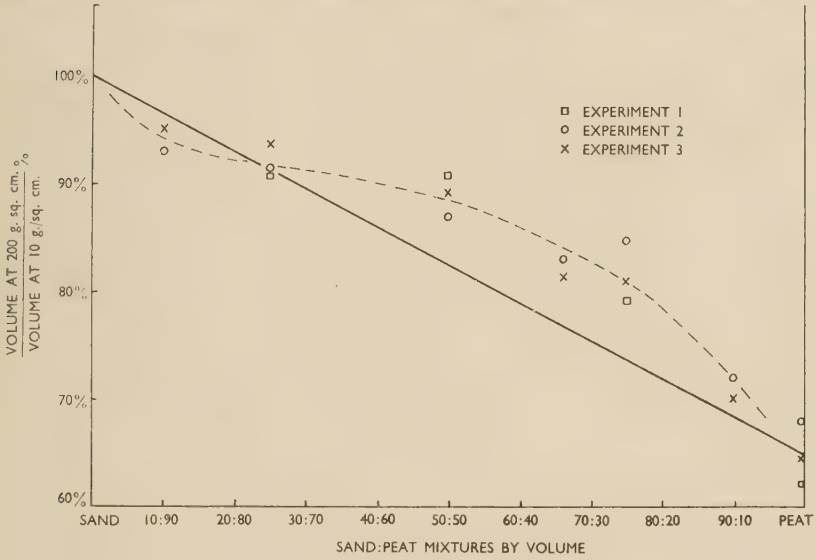
**Figure 5—Compressibility of peats**



This apparatus was also used to study the compression of wet peat. To 25 g. samples of air dry peat, successively increasing amounts of water were added. One set was left for 15 minutes and the other $4\frac{1}{2}$ hours before compression. The wetted peat was placed in the cylinder and compressed; the point at which water was expelled was noted. The results are shown in Table 6.

These results give general confirmation of results described earlier on the absorption of water. A greater pressure was needed to express water from peat soaked several hours than from peat soaked a few minutes.

**Figure 6—Decrease in volume of peat: sand mixtures by compression**




All points are the means of 2 or more measurements. The straight line shows the expected relationship

**Table 6. Removal of water from peat by direct pressure**

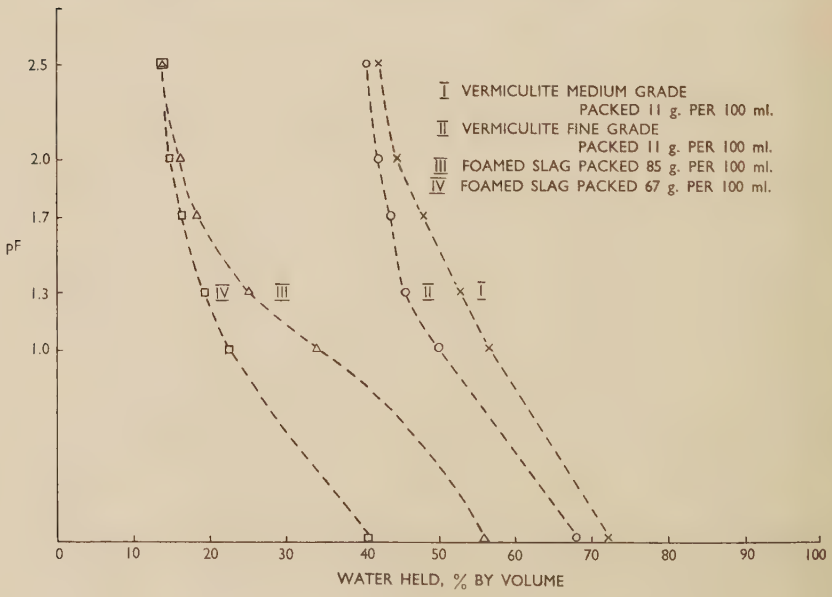
| Volume of water added to 25 g. peat | Pressure (g./sq. cm.) at which water was expelled | |
|---|---|---|
| | After 15 minutes soaking | After $4\frac{1}{2}$ hours soaking |
| 50 ml. | > 200 | > 300 |
| 75 | > 200 | > 300 |
| 100 | 100 | 300 |
| 125 | 20 | 200 |
| 150 | 0 | 60 |

## Moisture-suction curves of other materials

The characteristics of materials which have already been used or considered for use as casing materials have been determined using the suction method and are shown in Figure 7. The curve obtained from the vermiculites is of interest as it shows that comparatively little water is held within the range pF 1·0 to pF 2·5. It is possible that much of the water held by vermiculite is not available for the mushroom and that this is one of the reasons why vermiculite alone or mixed with sand has been found to be unsuitable as a casing material. The results of casing experiments with vermiculite and vermiculite-sand mixtures are described in the Annual Report for 1952, where the poor results were attributed to a high magnesium content.

It was found that vermiculite was very difficult to wet by the methods previously described. Boiling for a few minutes was successful but the disintegration of the aggregates was considerable. Heating under pressure, 5 lb./sq. in. for 5—15 minutes, was successful and the amount of disintegration was reduced. It seems probable that air spaces exist within the aggregates which are completely sealed off, boiling expands and bursts them allowing complete saturation. This would account for the 10% to 20% which could not be saturated by milder treatments such as soaking in hot water, detergents or under reduced pressure. Some difficulty was also experienced with the foamed slag but this was not investigated.

**Figure 7—Moisture suction curves of vermiculite and foamed slag**



**Discussion and conclusions**

From the work reported here and in the Annual Report for 1953, several conclusions can be drawn. The amount of water held by any particular type of peat is affected by several factors:—

1. The density of packing.
2. The degree of saturation.
3. Particle size.
4. The previous treatment, particularly with regard to excessive drying.

Thus water holding characteristics obtained by soaking peat and subjecting it to suction have significance only for the conditions under which the determinations are carried out. The variations in water holding properties caused by alterations in any or all of these factors are liable to be large so that comparisons between types of peat in the laboratory and in use on a mushroom bed are difficult, and of doubtful accuracy even when allowance is made for each factor.

Another complicating factor is the variation found between different bales of the same type of peat.

Useful information has been obtained on the absorption of water by peats. The main obstacle to wetting has been found to be trapped air. Methods of removing most of this air have been investigated and several methods of completely saturating peat in an hour or so without detrimental effect have been found. Some of these methods could be applied to practice if necessary.

A standard method of saturating peats for laboratory work has been described.

The movement of water in peats has been investigated and the information obtained will prove helpful in considering the function of casing materials.

In view of the difficulties involved in measuring water holding capacity, pore space and related properties of peats it is concluded that for experimental purposes it is desirable to use a material which is less variable. The difficulties in using peat arise mainly from its compressibility and tendency to contain a large proportion of trapped air when wetted.

Several materials are being examined as alternatives.

**Advisory work**

In contrast to the steady rise in the number of samples received over the past few years, in the nine months of this year fewer than 20 samples were received. Most of these were samples of compost. It is difficult to assess the reason for the decrease in the samples of casing materials. Probably for many growers the use of peat and similar materials has eliminated the problem of selecting a suitable soil. The range of peat types available is fairly limited and questions of individual suitability as a casing are less likely to occur.

# CROPPING EXPERIMENTS

## R. L. Edwards

### Experiment 27

Six mixtures of sand and sphagnum peat were used for casing, each receiving two watering treatments; one was described as normal, and in the other an additional light watering was given between each two normal waterings, which meant in practice an average of one extra watering per week. Watering started two weeks after casing. At no stage did the difference in watering produce any important effect.

The composition of the mixtures, some of their properties, and the results obtained are given in Table 7.

Many other properties were recorded but they are not all given here because they do not show any evidence of direct effect on results.

The main feature of the results is the sharp difference between A, B and C which gave similar yields, etc., and D, E and F, which cropped later and gave lower yields. Most of the physical properties of the soils were graded in accordance with the proportion of peat to sand, or else showed no consistent trend at all. The only property which showed a sharp change from D to E was the pF of the mixtures at casing.

**Table 7. Casing mixtures and results, Experiment 27**

| Mixture | B | C | D | E | F | G |
|---|---|---|---|---|---|---|
| Sand .. .. | 600 | 600 | 600 | 600 | 600 | 600 lb. |
| Sphagnum peat .. | 240 | 90 | 40 | 24 | 15 | 10 lb. |
| Carbonate of lime | 48 | 18 | 8 | 4·8 | 3 | 2 lb. |
| Water .. .. | 96 | 36 | 16 | 9·6 | 6 | 4 gallons |
| Dry pore space .. | 74 | 63 | 56 | 54 | 50 | 42% by volume |
| Moisture at casing | 50 | 40 | 25 | 18 | 13 | 9% by volume |
| pF at casing .. | 1·4 | 1·5 | 1·7 | over 2·5 | over 2·5 | over 2·5 |
| First pinheads .. | 39 | 39 | 40 | 45 | 45 | 47 ± 0·8 } days from |
| First picking .. | 47 | 48 | 48 | 52 | 52 | 55 ± 1·0 } spawning |
| Fruiting— | | | | | | |
| 4 weeks.. .. | 31 | 28 | 27 | 24 | 25 | 25 ± 1·7 } mushrooms |
| 8 weeks.. .. | 48 | 46 | 41 | 37 | 37 | 42 ± 2·0 } per sq. ft. |
| final .. .. | 56 | 55 | 50 | 42 | 42 | 46 ± 2·1 } per sq. ft. |
| Yield— | | | | | | |
| 4 weeks.. .. | 15 | 15 | 15 | 15 | 16 | 17 ± 0·5 } oz. per |
| 8 weeks.. .. | 24 | 24 | 23 | 24 | 24 | 26 } oz. per |
| final .. .. | 28 | 29 | 27 | 26 | 27 | 29 } sq. ft. |

These mixtures were mixed and applied to the beds wet, as is usual with peat casing, and as the peat is the effective moisture holding agent, the amount of water added was based on the peat content of the mixture. It was discovered later, that this had resulted in a much higher pF in mixtures E, F, and G; i.e., the water in these mixtures was much more tightly held than in the others, and would be less readily available to the mushroom (or of course for less directly related functions such as protection of the compost from drying). This difference would persist until watering started two weeks after casing. When samples of the casings were analysed later in the cropping period the range of pF values was similar in all six mixtures, but the difference in number of mushrooms produced persisted throughout the crop.

**Experiment 28**

In this experiment three of the same casing mixtures as in Experiment 27 were used, B, D and F, but beds were cased with two depths, 1 and 2 inches of casing, as well as receiving the same two watering treatments. This experiment was started a month after No. 27, so that the results of that experiment were not known until this one was almost completed. There were no differences in time of cropping, number of mushrooms or final yield.

**Experiment 29**

Two casing mixtures were used, B which was very porous and C containing 50% sand by volume, resulting in a much lower moisture holding capacity and pore space. These were applied in two depths of casing, so that the extra thickness of C could hold at least as much

**Table 8. Effect of casing mixture and depth**

| Casing Mixture | B | B | C | C |
|---|---|---|---|---|
| Sphagnum peat .. | 45 | 45 | 50 | 50% by volume |
| Sand .. .. .. | 10 | 10 | 50 | 50% „ „ |
| Vermiculite .. .. | 45 | 45 | | „ „ |
| Depth of casing .. | 1·5 | 3 | 1·5 | 3 cm. |
| First pinheads .. | 44 | 44 | 44 | 45 days from spawning |
| First picking .. | 48 | 49 | 49 | 50 „ „ „ |
| Fruiting— | | | | |
| 4 weeks .. .. | 24 | 24 | 22 | 20 mush. per sq. ft. |
| 8 weeks .. .. | 56 | 54 | 46 | 53 „ „ „ „ |
| final .. .. | 65 | 68 | 62 | 64±2·5 |
| Yield— | | | | |
| 4 weeks .. .. | 0·7 | 0·8 | 0·7 | 0·7 lb. per sq. ft. |
| 8 weeks .. .. | 1·4 | 1·4 | 1·3 | 1·4 „ „ „ „ |
| final .. .. | 1·6 | 1·8 | 1·7 | 1·7 „ „ „ „ |

water as the thinner layer of B; three systems of watering were practised, watering on two days, Tuesday and Friday, three days, Monday, Wednesday and Friday, and six days, Monday to Saturday, each week. On each occasion the beds were watered as evenly as possible, and a check on this was provided for one shelf of twelve beds by weighing petri dishes placed on the beds. The object of varying the watering was to cover the range between a slight surplus and a slight lack of water. In practice evaporation from the beds was small, much smaller than in the previous experiment on these lines, No. 27, and although the waterings were made progressively lighter it is doubtful whether any beds ever really suffered from excessive dryness. The cropping results are shown in Tables 8 and 9. None of the watering treatments produced significant differences; the more porous soil in greater thickness gave the best crop.

**Table 9. Effect of watering treatment**

| | | | |
|---|---|---|---|
| Beds watered .. | 2 | 3 | 6 times weekly |
| First pinheads .. | 45 | 44 | 44 days from spawning |
| First picking .. | 49 | 49 | 49 „ „ „ |
| Fruiting— | | | |
| 4 weeks .. .. | 45 | 45 | 43 mushrooms per sq. ft. |
| 8 weeks .. .. | 50 | 54 | 53 „ „ „ „ |
| 12 weeks .. .. | 65 | 66 | 64 „ „ „ „ |
| Yield— | | | |
| 4 weeks .. .. | 0·7 | 0·8 | 0·7 lb. per sq. ft. |
| 8 weeks .. .. | 1·3 | 1·4 | 1·4 „ „ „ „ |
| 12 weeks .. .. | 1·7 | 1·7 | 1·7 „ „ „ „ |

**Experiment 30**

Three casing mixtures were used as shown in Table 10. Their moisture holding capacities were in the descending order B, A, C. Unlike previous experiments, in this one the mixture with the lowest capacity gave the best result. The result may have been affected by the fact that the house was in crop at a time of moderate temperature and fairly high humidity, so that there would not be very rapid evaporation from the beds.

Four depths of casing were used, from 0·6 inch to 2 inches and the deepest of these gave most mushrooms and the highest yield. (Table 11).

One of the six shelves used for this experiment was filled with compost made with urea as source of nitrogen. In previous experiments this had been done by dissolving the urea in water and spraying it on the stack, but this time it was included in a dry mixed activator, as is done with dried blood. The mixture was quite free-running and easy to handle and distribute in the compost. The yield obtained cannot be compared at all accurately with those from other shelves, because there was no replication, but it was not significantly different from that obtained from the corresponding shelf filled with standard MRA compost.

**Table 10. Casing mixtures and results**

| Mixture | A | B | C |
|---|---|---|---|
| Sphagnum peat .. | 15 | 9 | 10 parts by volume |
| Vermiculite .. .. | | 9 | |
| Sand .. .. .. | 5 | 2 | 10 „ „ „ |
| First pinheads .. | 37 | 42 | 38 days from spawning |
| First picking.. .. | 44 | 48 | 44 „ „ „ |
| Fruiting— | | | |
| 4 weeks .. .. | 36 | 32 | 37 mushrooms/sq. ft. |
| 8 weeks .. .. | 52 | 47 | 59 „ |
| final .. .. | 63 | 58 | 70±3·1 „ |
| Yield— | | | |
| 4 weeks .. .. | 1·2 | 1·1 | 1·3 lb./sq. ft. |
| 8 weeks .. .. | 1·8 | 1·7 | 1·9 „ |
| final .. .. | 2·1 | 2·0 | 2·3 „ |
| Av. size .. .. | 0·53 | 0·55 | 0·53 oz./mushroom |

**Table 11. Depth of casing**

| Depth | 1·5 | 2·5 | 3 | 5 cm. |
|---|---|---|---|---|
| First pinheads .. | 39 | 39 | 39 | 39 days from spawning |
| First picking .. | 45 | 45 | 45 | 46 „ „ „ |
| Fruiting— | | | | |
| 4 weeks .. .. | 33 | 32 | 35 | 40 mushrooms/sq. ft. |
| 8 weeks .. .. | 47 | 47 | 55 | 63 „ |
| final .. .. | 57 | 58 | 66 | 74±3·7 „ |
| Yield— | | | | |
| 4 weeks .. .. | 1·2 | 1·1 | 1·2 | 1·4 lb./sq. ft. |
| 8 weeks .. .. | 1·6 | 1·6 | 1·9 | 2·1 „ |
| final .. .. | 1·9 | 2·0 | 2·2 | 2·3 „ |
| Av. size .. .. | 0·54 | 0·55 | 0·52 | 0·52 oz./mushroom |

**Evaporation from casing soil**

In Experiments 27 and 29 the rate of evaporation from the casing was studied by daily weighing petri dishes placed on the beds. The outsides and bottoms of dishes were carefully wiped before weighing. On days when the beds were watered dishes were weighed immediately before and after watering.

The presence of the dishes was ignored as far as was humanly possible and the beds were watered evenly so that the dishes should collect a representative sample of the water applied.

It is known that under typical outdoor conditions evaporation from wet soil or from a covering crop with a good supply of moisture is similar to that from an open water surface. By using pairs of petri

dishes, one empty and the other filled with casing material, a similar comparison was made in these experiments.

These observations in Experiment 27 were made during April, and those in Experiment 29 during July, when the heating system was not in use, and the conditions generally were of moderate temperature and higher humidity than in April. This is reflected in lower rates of evaporation in the later experiment.

For comparison with normal beds, an evaporation of 2·5 g. per dish is equivalent to six gallons from 1,000 sq. ft. and that is the rate observed during the first day after watering the beds in April. During July the rate was down to $2\frac{1}{2}$ gallons per 1,000 sq. ft. per day.

In April the rate of evaporation was such that empty dishes sometimes dried out after the first day and the additional waterings given to some beds (treatment Q) provided water for increased evaporation. In fact evaporation was being limited by the quantity of water applied to the beds.

The principal comparisons of interest are given in Table 12.

**Table 12. Daily evaporation rates in April, Experiment 27**

| Casing | First | Second day after watering | | |
|---|---|---|---|---|
| B .. | 2·2 | 2·0 | | g. per dish |
| C .. | 2·5 | 2·4 | | ,, ,, ,, |
| D .. | 2·8 | 2·0 | ±0·24 | ,, ,, ,, |
| E .. | 2·0 | 1·3 | | ,, ,, ,, |
| F .. | 2·5 | 1·7 | | ,, ,, ,, |
| G .. | 2·8 | 1·5 | | ,, ,, ,, |
| All casings .. | 2·5 | 1·8 | ±0·10 | ,, ,, ,, |
| Petri dishes empty | 2·4 | 1·4 | ±0·14 | ,, ,, ,, |
| Petri dishes cased | 2·5 | 2·3 | | ,, ,, ,, |
| P (normal watering) | 2·15 | 1·61 | ±0·14 | ,, ,, ,, |
| Q (extra watering) | 2·75 | 2·03 | | ,, ,, ,, |

**Table 13. Daily evaporation rates in July, Experiment 29**

| Casing and depth | First | Second day after watering | |
|---|---|---|---|
| B 1·5 cm. .. | 0·9 | 1·0 | g. per dish |
| B 3·0 cm. .. | 0·9 | 1·3 | ,, ,, ,, |
| C 1·5 cm. .. | 0·9 | 1·0 | ,, ,, ,, |
| C 3·0 cm. .. | 0·9 | 1·5 | ,, ,, ,, |
| Beds watered— | | | |
| 2 times weekly.. | 0·7 | 1·4 | ,, ,, ,, |
| 3 ,, ,, .. | 1·0 | 1·0 | ,, ,, ,, |
| 6 ,, ,, .. | 1·1 | | ,, ,, ,, |
| Petri dishes empty | 1·0 | 1·2 | ,, ,, ,, |
| Petri dishes cased | 0·9 | 1·2 | ,, ,, ,, |

The quantities applied were 4—8 g. per dish at each watering in April, corresponding to 1—2 g. per dish per day.

In July watering started earlier and was heavier, and evaporation was naturally slower, so that the beds probably tended always to have a reserve of moisture. Under these conditions the various treatments applied had much less effect on the rate of evaporation. (Table 13.)

The waterings in July started at 5 g. per dish and were gradually reduced to 1 g. per dish as it was observed that evaporation was so much slower.

It has not been possible to relate these observations on evaporation to the yields produced, but they may be of some practical interest in relation to watering practice on commercial farms under various seasonal or other conditions.

# MICROBIOLOGY DEPARTMENT
## D. G. Gandy

During the first nine months of 1954, 61 samples were received by the Microbiology Department and examined. Eelworms and cecids were still the most frequently encountered pests.

The following is a list of the more important organisms found in samples together with the number of times each was identified.

**Parasitic on mushrooms**

| | |
|---|---|
| *Mycogone perniciosa* | 1 |

**Competitors or Invaders**

| | |
|---|---|
| *Papulaspora byssina* | 1 |
| Yellow moulds | 2 |
| *Scopulariopsis fimicola* | 4 |
| *Trichoderma viride* | 1 |
| " Bacterial pit " | 1 |
| " Bacterial rot " | 2 |
| *Corticium sp.* | 2 |
| *Penicillium sp.* | 1 |
| " Geotrichum " | 1 |

**Pests**

| | |
|---|---|
| Nematodes (parasitic and saprophytic) | 36 |
| Cecids | 22 |
| Mites | 3 |
| Sciarid larvae | 1 |
| Enchytraeids | 1 |

**Studies on " Bacterial pit "**

Experiments have continued with the object of ascertaining the method of transmission of this disease. In previous experiments already described bacterial suspensions were sprayed on to the casing material. Some pitted mushrooms were produced but in such small numbers that there was some doubt that the disease is transmitted through the casing rather than the air.

A further experiment was carried out in which nine 6 sq. ft. beds were used. Six were cased with fresh soil, three of these being left as controls and the others being sprayed with a bacterial suspension. The remaining beds were cased with similar soil removed from beds which were producing pitted mushrooms. Before being used, coarse mycelium and pinheads were removed from the soil and it was re-limed. The results are summarised in Tables 14 and 15.

**Table 14. Total number of mushrooms produced in 7 weeks**

| Treatment | Healthy | | Diseased | | Total | |
|---|---|---|---|---|---|---|
| | no. | wt. oz. | no. | wt. oz. | no. | wt. oz. |
| Control—fresh casing soil .. .. | 100 | 102 | 0 | 0 | 100 | 102 |
| Fresh casing inoculated with bacterial suspension .. .. .. .. | 106 | 104 | 5 | 4 | 110 | 108 |
| Used casing from infected beds .. | 124 | 80 | 88 | 60 | 212 | 140 |

**Table 15. Percentage of diseased mushrooms in total picked each week**

| | Week | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Suspension .. .. | 0 | 15% | 5% | 0 | 9% | 0 | 0 |
| Used casing .. .. | 90% | 49% | 41% | 33% | 33% | 5% | 0 |

Two interesting points should be noted in connection with these results; firstly there were no diseased mushrooms on the control beds, showing that airborne infection is not a serious risk even when diseased and healthy beds are in close proximity to each other. Secondly that although there was a large percentage of infection on beds having old casing this percentage declined rapidly, showing that the environmental conditions existing during the experiment were not favourable for the continuance and spread of the disease. The average relative humidity of the atmosphere during cropping was 82% with a maximum of 96% and a minimum of 56%. Average temperature was 70° F., minimum 65° F. A high temperature was maintained in these experiments to induce a satisfactory incidence of disease.

An examination of the replies given on the last MRA questionnaire showed that there appeared to be a correlation between the incidence of bacterial pit and the use of carbonate of lime in casing soil. Accordingly an experiment was carried out in which four beds were cased with used casing to which hydrated lime was added, and four beds were cased with used soil plus carbonate of lime. Two levels of humidity were employed:—namely the normal disease room atmosphere which showed daily fluctuations, and a steady high humidity obtained by hanging wet sacking in front of the beds. This also served to restrict ventilation to some extent. The average disease room humidity from the time of casing onwards was 91·7% with a maximum of 98% and a minimum of 64%. The higher humidity region remained fairly constant at about 92%. Mean temperature was 68° F., maximum 69° F., minimum

**Table 16. Total number of mushrooms produced in 5 weeks**

| Treatment | Healthy | | Diseased | | Total | |
|---|---|---|---|---|---|---|
| | no. | wt. oz. | no. | wt. oz. | no. | wt. oz. |
| High humidity, hydrated lime .. | 16 | 18 | 53 | 62 | 69 | 80 |
| High humidity, carbonate of lime | 1 | 1 | 103 | 93 | 104 | 94 |
| Fluctuating humidity, hydrated lime | 17 | 24 | 30 | 33 | 47 | 56 |
| Fluctuating humidity, carbonate of lime .. .. .. .. .. | 35 | 32 | 82 | 58 | 117 | 89 |

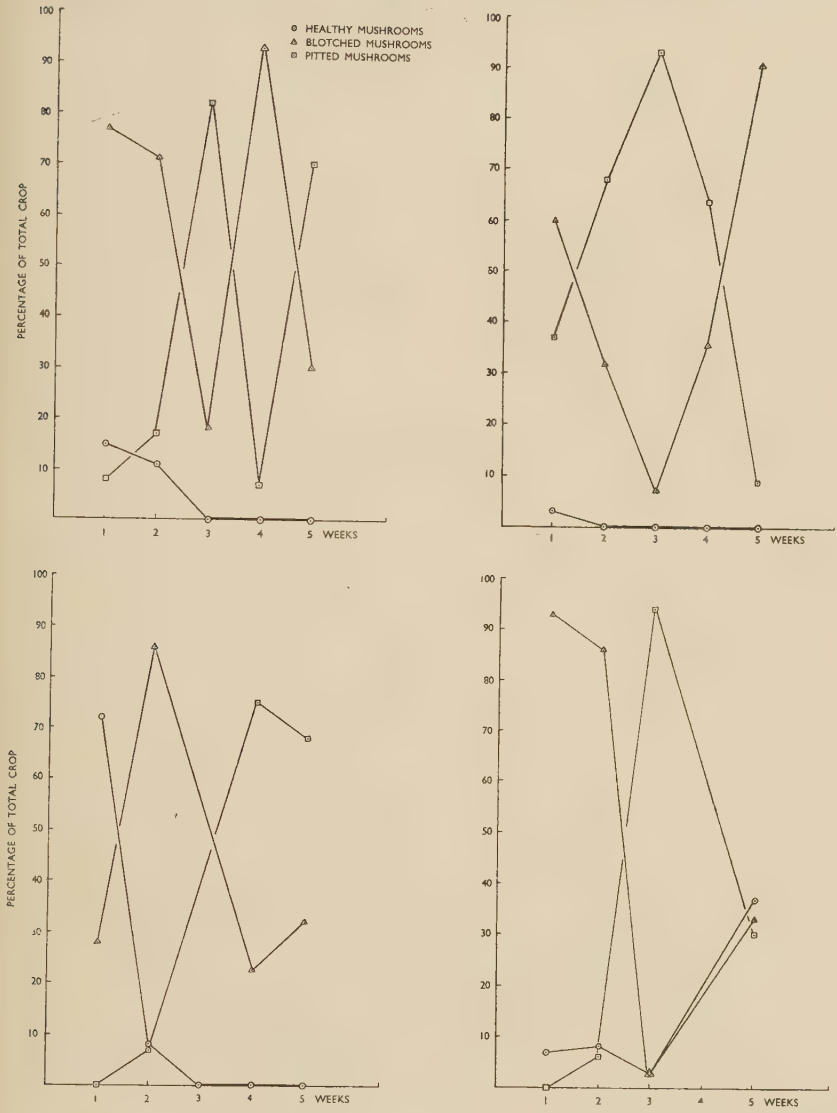
**Table 17. Percentage of diseased mushrooms in total picked each week**

| | Week | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| High humidity, hydrated lime .. .. | 8% | 34% | 82% | 8% | 70% |
| High humidity, carbonate of lime .. | 37% | 68% | 92% | 64% | 10% |
| Fluctuating humidity, hydrated lime .. | 0 | 6% | 0 | 65% | 58% |
| Fluctuating humidity, carbonate of lime.. | 0 | 6% | 92% | 0 | 30% |

66°F. A high rate of bacterial pit infection was obtained but the results of this single experiment did not show any clear correlation between the type of lime used and the incidence of pit. The results are summarised in Tables 16 and 17.

It was noted that the beds from which the casing soil was taken for this experiment were producing, in addition to pitted mushrooms some in which the caps were disfigured by brown blotches. This condition was transmitted through the casing, to the experimental beds. These mushrooms are not included in the numbers shown in Table 16. Two interesting points noted in connection with the incidence of this condition were:—firstly on only one occasion on a single bed were mushrooms found having both pits and blotches and secondly the incidence of blotch increased when pit decreased and vice versa. (See Figure 8).

**Figure 8—Proportions of healthy, blotched and pitted mushrooms**



**Yellow Moulds**

Among the cultures of yellow moulds received from the U.S.A. at the end of 1953, there was one of *Myceliophthora lutea*. Early in 1954, two cultures of *M. lutea* were also received from France. Whilst all three differ somewhat in colour and texture, the general habit of growth and spore dimensions agree reasonably well with the description published by Costantin (1), (2) except that no chlamydospores have been seen even when the moulds were grown in compost. Samples of yellow moulds obtained from seventeen growers were compared with the cultures of *M. lutea* and none were found to correspond. Five different moulds were found in these samples but two of them were only found in one sample, leaving three which appear to be common in compost under widely differing conditions.

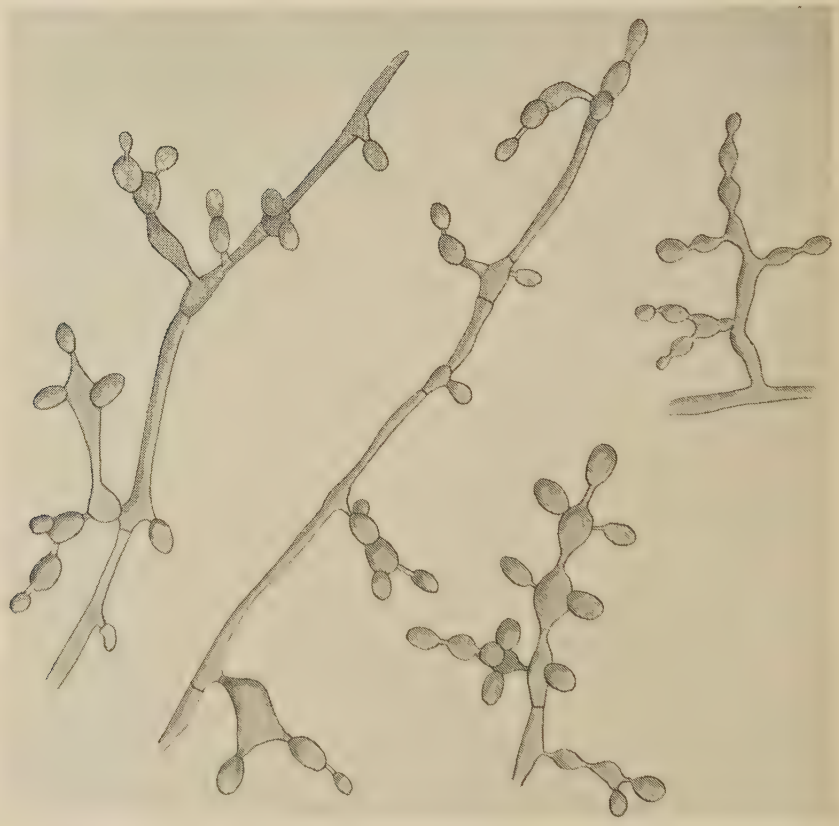


**Fig. 9.** *Myceliophthora lutea* (×**1500**) **(camera lucida drawing)**

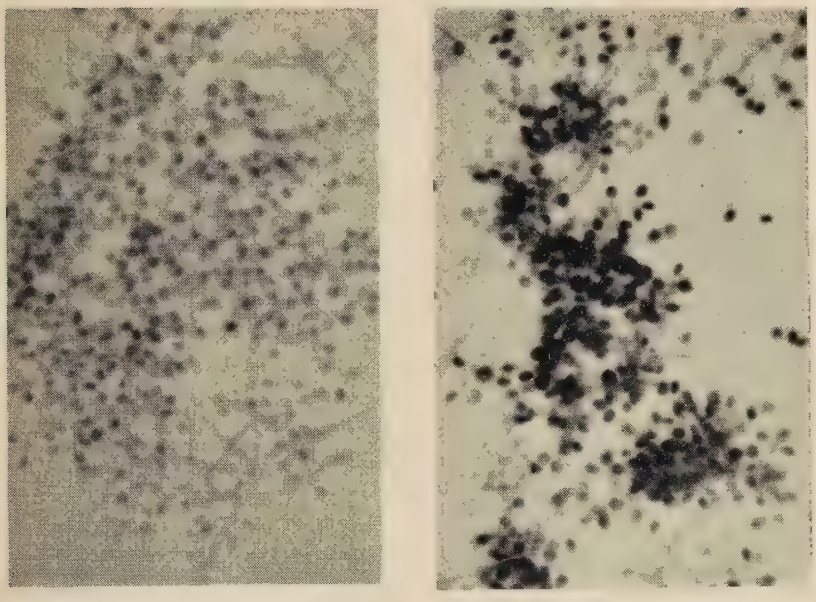


**Fig. 10.** *Myceliophthora lutea* (×600). **Photo : D. G. Gandy**

These three fungi have not yet been identified, so for convenience they are referred to as Ym 1, Ym 2, Ym 3 in the following description.

**Ym 1**

Mycelium at first white, velvety, generally appearing first round the piece of spawn (i.e., in the region of oldest mycelium). At maturity the fungus turns pale lemon yellow with a characteristic chlorine like odour. The mycelium is very fine, disappearing after spore formation. Spores echinulate (" spiny "), round, 4—7μ diam.

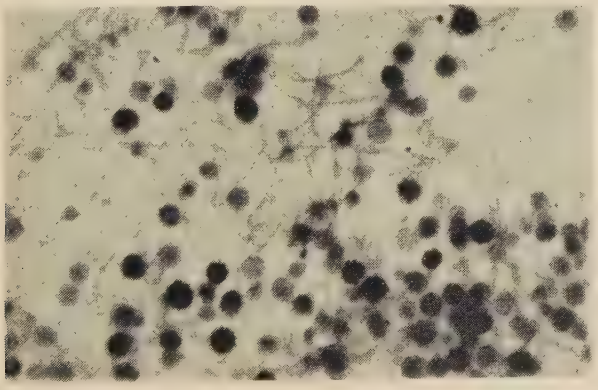


**Fig. 11. Ym. 1.** (×600). **Photo : D. G. Gandy**

**Fig. 12. Ym 1 (×1500) (camera lucida drawing)**

**Ym 2**

Mycelium at first white, forming well defined globular colonies which may coalesce to form large patches. At maturity colonies become

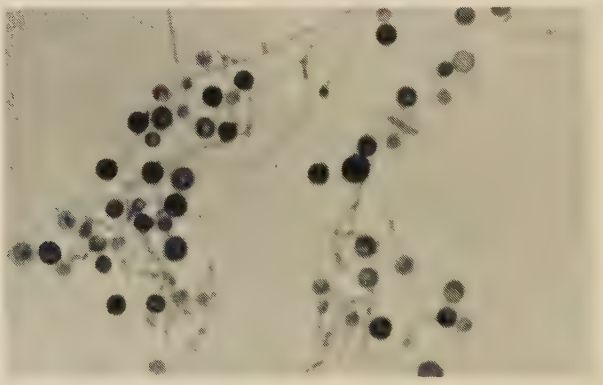


**Fig. 13. Ym 2 (×600). Photo : D. G. Gandy**

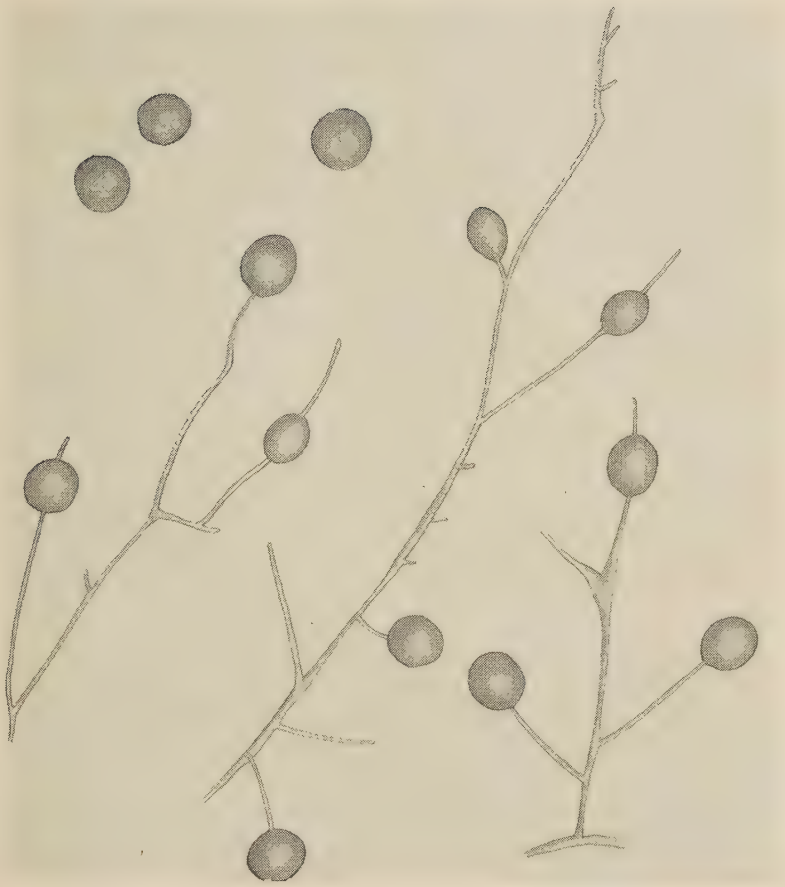


**Fig. 14. Ym 2 (×1500) (camera lucida drawing)**

yellowish-brown in colour. Mycelium very fine, disappearing after spore formation. Spores smooth, round, 4—7$\mu$ diam.

**Ym 3**

Mycelium white, turning greenish yellow at maturity. Colonies small fluffy and localised. Spores ovoid 1·8—2·25 × 2·25—3·6$\mu$, with a conspicuous oil drop.

Both Ym 1 and Ym 2 commonly spread throughout the compost but Ym 3 does not appear to do so.

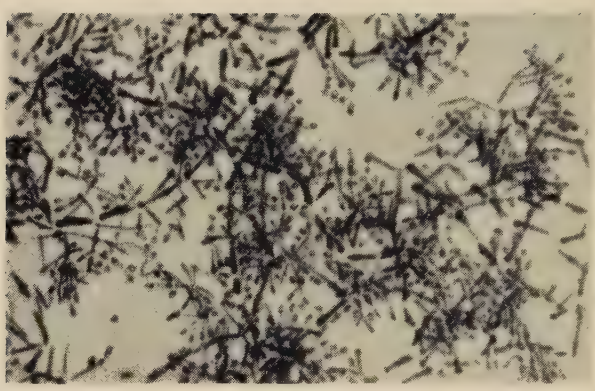


**Fig. 15. Ym 3 (×600). Photo : D. G. Gandy**

**Fig. 16. Ym 3 (×1500) (camera lucida drawing)**

Whilst these fungi may be present in mushroom beds in quite large amounts, it has not yet been established experimentally whether any of them are detrimental to mushroom production.

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